NOTES ON OXYGEN PRODUCTION IN CORAL PLANULAE

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WITH TWO TEXT-FIGURES

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INTRODUCTION.

IT has long been known that the tissues of reef-building corals contain enormous numbers of symbiotic algal cells, and in the preceding paper in this volume by Yonge, Yonge and Nicholls it has been shown that, under suitable illumination, a coral will behave like a plant, producing an excess of oxygen and taking up carbon dioxide from the sea-water. Although in their early stages the eggs of a coral are not infected with algal cells, the planulae when liberated contain them to the number of several thousand. Some experiments were therefore made to see how the metabolism of the larval coral is affected by the symbiotic algae which it contains.

The two species of coral with which these observations deal are *Porites*, sp., and *Pocillopora bulbosa*. They were among the most common of the corals on the reef flat of Low Isles, and were the only species found giving off planulae in numbers sufficient for experimental work. Although *Porites* produced planulae whenever it was collected (from January to July), production in *Pocillopora* was discontinuous, and was apparently related to the phases of the moon. Collections were therefore made every few days and the production of planulae noted, in the case of *Porites* from January to July, in the case of *Pocillopora* during January and from March to July. A detailed account of the results from these collections will be found in Vol. III of these reports.

PORITES.

Porites produced planulae continuously, although in varying numbers, during the whole period of observation. In June and July the numbers were considerably lower than from January to May. The planulae varied much in size and colour, the colour being dependent on the number of algal cells present. Since their contour altered continually, exact measurements were not possible in the living state, but they were about 0·5 to 1 mm. in length and from 0·2 to 0·5 mm. in width. The symbiotic algal cells were counted in five planulae, two very pale, one medium and two dark-coloured, and the numbers were respectively 1150, 1800, 2340, 6500 and 7400.

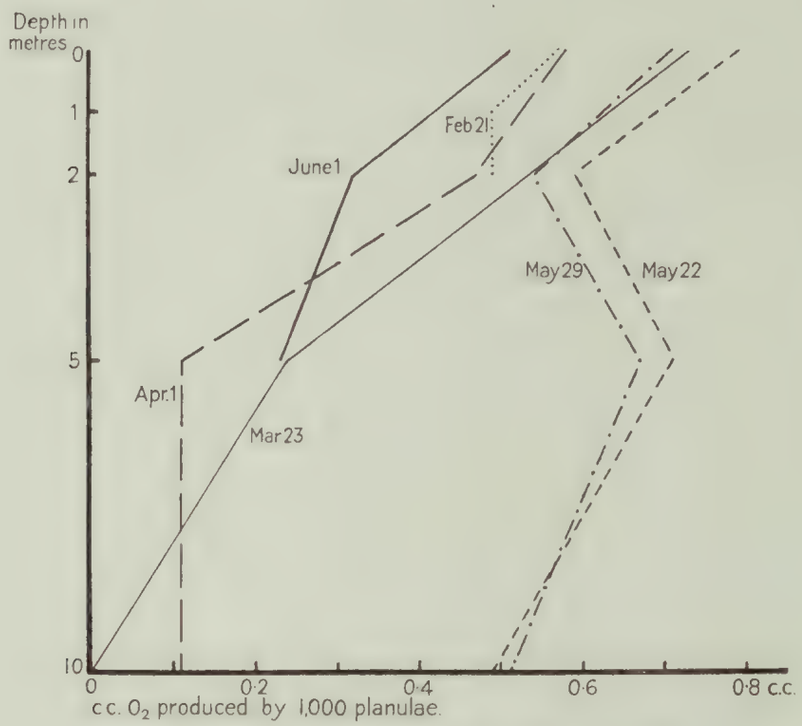

FIG. 1.—Oxygen production in *Porites* planulae.

Experiments were made to find out how far the photosynthesis of the algal cells affected the oxygen exchange of the planulae as a whole, both at the surface of the sea and at depths of a few metres. Since there was no sheltered position near the island with a depth greater than 14 metres, experiments were not carried out deeper than 10 metres. The required number of planulae was put in filtered sea-water into well-stoppered clear glass bottles, and these bottles were fixed in wire cages and attached at different depths to a buoyed and anchored rope in the sea. Opaque bottles (painted black and enclosed in a dark cloth bag) were used to measure the respiration, and these were either suspended in the cages along with the clear glass bottles, or kept in a dark box in the aquarium where the temperature was fairly low and constant. The sea-water used in the experiments was twice filtered, first through filter-paper, and then through a Jena sintered-glass filter as described by Yonge and Nicholls (Vol. I, No. 7 of these reports), but in spite of this precaution the oxygen content always fell slightly during the course of an experiment. The fall in oxygen content of sea-water with time is a wide-spread phenomenon, and

depends on the oxidation of organic matter present. It is more rapid in tropical than in temperate waters. Control bottles also, containing filtered sea-water only, were therefore used during every experiment. After exposure for 24 hours the bottles were brought in and the oxygen content estimated by Winkler's method. The difference in oxygen content between the control and the opaque bottle gave the amount used up by the planulae in respiration; the difference between the opaque bottle and the light bottle gave the total amount of oxygen produced by the algae; the difference between the control and the light bottle gave the oxygen exchange of the planulae as a whole. The last almost always showed that there was a loss in oxygen during the course of an experiment, proving that production by photosynthesis does not make up for loss by respiration.

Some difficulty was encountered in choosing a suitable number of planulae to put in the experimental bottles available. The planulae vary so much both in size and in number of algal cells present that a comparatively large number is necessary for a representative sample, but, on the other hand, if the oxygen content of the bottles be much reduced, the consumption will be irregular. The number used in early experiments (500 in a bottle of about 120 c.c. capacity) was undoubtedly too high, and duplicate bottles often gave discordant results. The number finally used (100 in a bottle) gave results which were more consistent and are probably the most reliable. The results from the dark bottles were usually rather irregular but the variation showed no relation to temperature or depth, and the average was therefore taken in calculating the results for an experiment.

TABLE I.—*Oxygen Production in* Porites *Planulae.*

Date.	Number of c.c. of O_2 produced by 1000 planulae at a depth of—					Number of c.c. of O_2 used by 1000 planulae in respiration.	Number of planulae in each bottle.	Comments.
	0 m.	1 m.	2 m.	5 m.	10 m.			
Jan. 30–31	..	..	0·87	..	..	..	500	6 hrs.' sunshine. Control lost.
Feb. 2–3	..	..	0·44	..	..	0·77	500	20 mins.' sunshine.
,, 4–5	..	..	0·56	..	..	0·77	500	1 hr. 25 mins.' sunshine.
,, 6–7	..	..	0·52	..	..	0·72	500	3 hrs. 45 mins.' sunshine.
,, 8–9	..	..	0·48	..	..	0·63	500	10 hrs. 30 mins.' sunshine.
,, 22–23	0·57	0·48	0·48	..	..	0·99	400	10 hrs. 20 mins.' sunshine.
Mar. 23–24	0·73	..	..	0·24	0·00	0·97	400	2 hrs. 25 mins.' sunshine. Water very turbid.
April 1–2	0·58	..	0·47	0·11	0·11	0·89	400	4 hrs. 55 mins.' sunshine.
May 22–23	0·79	..	0·59*	0·71	0·49	0·85	100	5 hrs. 20 mins.' sunshine.
,, 29–30	0·71	..	0·54*	0·67	0·51	0·82	100	9 hrs. 55 mins.' sunshine.
June 11–12	0·51	..	0·32	0·23	..	0·80	100	No sunshine.

The results (Table I and Fig. 1) are calculated as the amount of oxygen used up or produced by a thousand planulae in 24 hours. They show that over 24 hours the oxygen produced by the symbiotic algae was never enough to balance that used by respiration, although on one or two occasions (*e. g.* 22nd May, 29th May) the amount produced and the amount consumed were nearly equal at the surface. Oxygen production usually

* Probably shadowed by the buoy.

decreased with depth, as might be expected, but the fall is only slight in clear weather (*e. g.* 8th March). In dull weather (*e. g.* 11th June) or when there is much sediment in the water (*e. g.* 23rd March) the fall is greater. On 23rd March the water was noticeably turbid, and the Secchi disc reading at the weekly hydrographic station on 25th March was only $4\frac{1}{2}$ metres, the usual reading being from 10-20 metres. The oxygen production on 23rd March fell from 0·73 c.c. at the surface to zero at 10 metres. The amount of oxygen produced at the surface bears no constant relationship to the amount of sunshine, but below the surface more is usually produced in sunny than in dull weather. The amount of oxygen produced by a thousand planulae in 24 hours varied from 0·5 c.c. to about 0·75 c.c. at the surface, and from 0 to 0·5 c.c. at 10 metres. The amount of oxygen used up in respiration varied from about 0·75 c.c. to about 1 c.c. In two experiments in sunny weather the bottles at 2 metres showed a lower oxygen content than those at 5 metres. This was probably because the 2-metre cage was so close beneath the buoy that it was shaded by it. In an experiment on 11th June, designed to test this point, the 2-metre cage was suspended from a floating stick attached to the buoy at one end, but the weather was overcast and the result (a regular gradient) is therefore inconclusive.

POCILLOPORA.

As has been stated, *Pocillopora* differed from *Porites* in that planula production was discontinuous. It was observed by Dr. Stephenson about the time of new moon in December, January and February, and after this collections were made every few days to find out whether it was restricted to this period only. Production took place only at

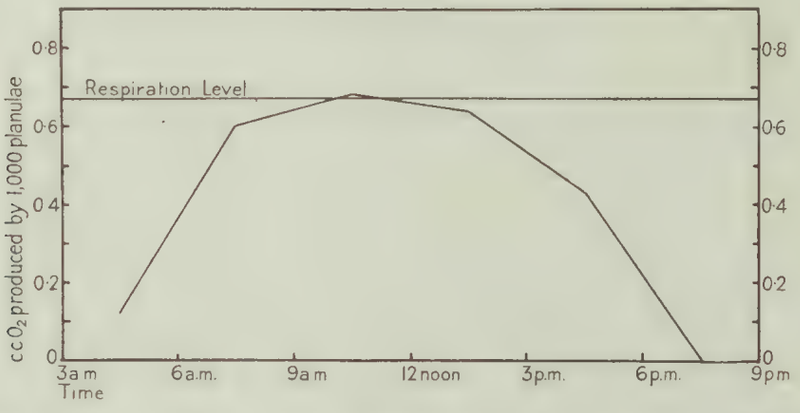

Fig. 2.—Oxygen production in *Pocillopora* planulae during the 24 hours, 21st to 22nd June.

or near new moon in March and April, and only at full moon in July. During May and June production was almost continuous, with a peak shortly after new moon in May and shortly before full moon in June. The planulae were larger than those of *Porites*, and varied as greatly in size and colour. The number of algal cells was not counted accurately, but in one dark-coloured specimen it was estimated by a partial count at 25,000.

The number of planulae used for experiments was at first too large (200 and 100 in a bottle), and no successful depth experiment was carried out.

On 21st June a series of experiments was carried out to find the amount of photosynthesis at different times of day at the surface (Table II and Fig. 2). The experiments lasted for 18 hours, and the bottles were changed every 3 hours. Two bottles were exposed in the surface float, while two dark bottles and two controls were kept in the aquarium over each 3-hour period. There were 150 planulae in each bottle. Before 6 a.m. and after 6 p.m. there was no significant production, but during the daylight hours, especially from 6 a.m. to 3 p.m., oxygen production was high and practically balanced oxygen consumption. The weather was unfortunately broken, partly sunny and partly overcast, but it seems probable that had the day been clear, there would have been an excess of oxygen produced during the daylight hours. Production was very steady during the brightest hours, and practically replaced loss by respiration during that time.

TABLE II.—*Oxygen Production in* Pocillopora bulbosa *Planulae, 21st to 22nd June.*

Time.	Light bottles: Oxygen exchange for 150 planulae.		Opaque bottles: Oxygen exchange for 150 planulae.		Total O_2 produced by photosynthesis in 1000 planulae.	Total O_2 used in respiration by 1000 planulae.	Sunshine.
	c.c. O_2.	Average.	c.c. O_2.	Average.	c.c.	c.c.	
3 a.m.—	−0·082	−0·082	·0·096		0·12		None.
6.07 a.m.	−0·082		−0·086				
6.07 a.m.—	−0·009	−0·010	−0·097		0·60		90 mins.
9.05 a.m.	−0·010		−0·088				
9.05 a.m.—	+0·007	+0·002	−0·086		0·68		60 ,,
12 noon	−0·004		−0·083	−0·100		0·67	
12 noon—	−0·003	−0·004	−0·094		0·64		55 ,,
3 p.m.	−0·005		−0·100				
3 p.m.—	−0·035	−0·036	−0·119		0·43		110 ,,
6 p.m.	−0·036		−0·121				
6 p.m.—	−0·117	−0·120	−0·118		0		None.
9 p.m.	−0·123		−0·110				
Total for 24 hours	..	..	..	..	2·47	5·33	5 hrs. 15 mins.
6 a.m., 21st—	−0·077						
6 a.m. 22nd	−0·066	−0·074	−0·132	−0·132	1·93	4·40	5 hrs. 15 mins.
	−0·080						

A number of bottles with 30 planulae in each were also put out for the 24 hours beginning at 6 a.m. on 21st June. The amount of oxygen produced was 1·93 c.c., as compared with 2·47 c.c. when the experiment was carried out in 3-hourly sections. Yonge, Yonge and Nicholls (Vol. I, No. 8 of these reports) found that on keeping corals in a closed jar, the amount of oxygen used up in an hour decreased after the oxygen content had fallen to about half the normal figure. This is a common observation in experiments on the respiration of animals (Burfield, 1928; Dakin and Dakin, 1925), and probably explains the discrepancy.

When the results as a whole are compared with those of Yonge, Yonge and Nicholls on adult corals, it is seen that the ratio of algal cells to coral tissue is not so great in the planula as in the adult. In experiments carried out during the daylight hours adult corals almost always show an excess of oxygen production over consumption, whereas planulae apparently do so only under favourable conditions. In an experiment lasting 24 hours, however, the adult, like the planula, consumes more than it produces. The planulae vary greatly in size and algal content, and this no doubt accounts for some of the irregular results.

I am much indebted to Mr. A. P. Orr and Mr. A. G. Nicholls for help in collecting the coral and in putting out some of the experiments, and to Mrs. C. M. Yonge for the records of sunshine.

CONCLUSIONS.

During a period of 24 hours the amount of oxygen produced by the symbiotic algae in a coral planula is not sufficient to balance the oxygen used up by the combined respiration of algae and coral, although an excess is probably produced during the brightest hours of a sunny day.

The oxygen produced by photosynthesis falls off with depth, but is still considerable at 10 metres except when the water is turbid.

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